A comparative study of degradation and performance of thin film photovoltaic generators versus a multi-crystalline generator

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2013 ECCE IEEE ENERGY CONVERSION CONGRESS & EXPO
DENVER, COLORADO, USA | SEPTEMBER 16-20, 2013

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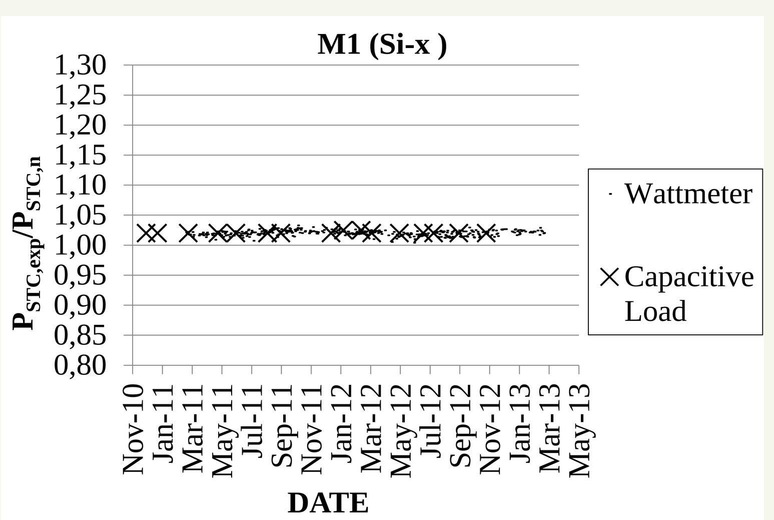
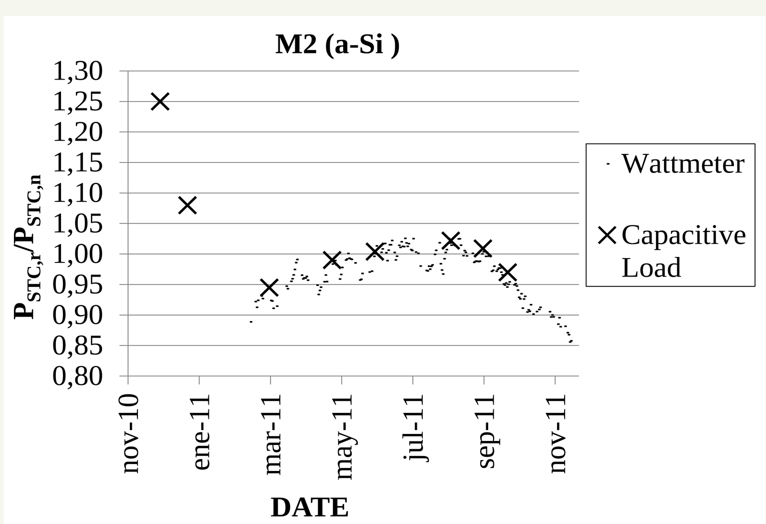
1. Abstract

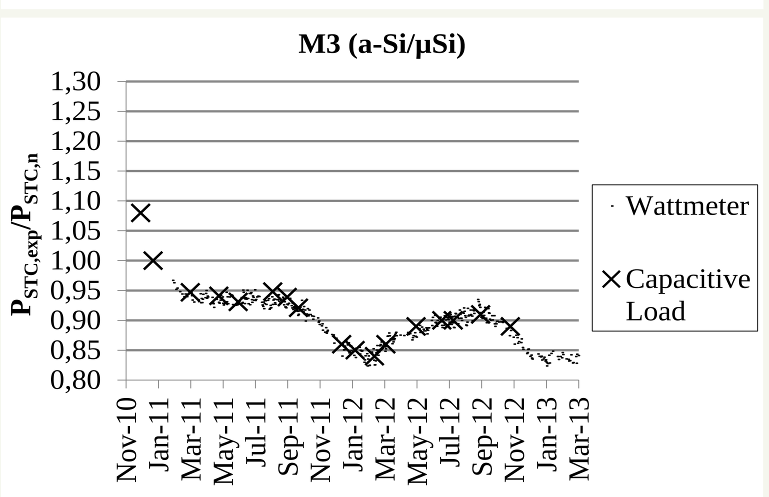
Thin film solar cells (TFSC) are supposed to have higher energy yield rates than crystalline silicon (Si-x) mainly possible by some enhancements like lower temperature coefficient and higher absorption of diffuse light. Although many studies have been carried out on this topic, there are uncertainties and there is no conclusive outcome to their performance compared to Si-x.

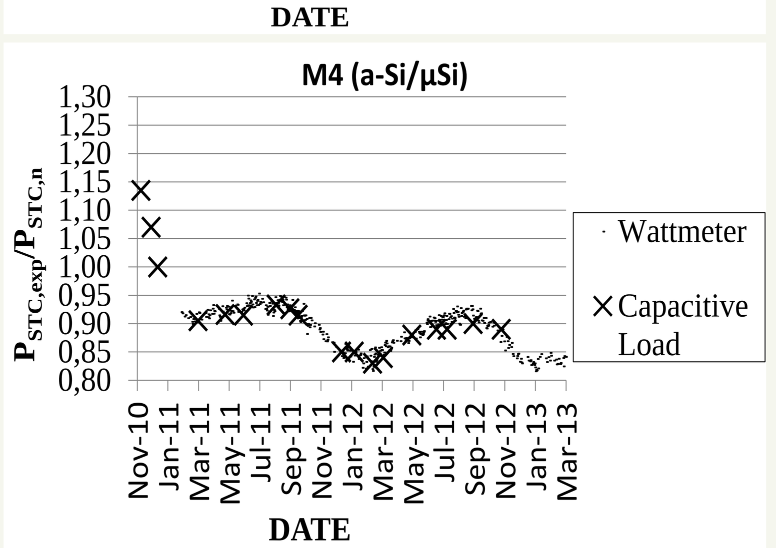
This work aims to contribute to the state of the art on this topic providing experimental data of degradation and performance of several commercially available TFSC generators (CdTe, CIGS, a-Si, a-Si/µSi) and a conventional Si-x. The energy yield of the TFSC generators during two years is compared to the Si-x one which is supposed to be the standard.

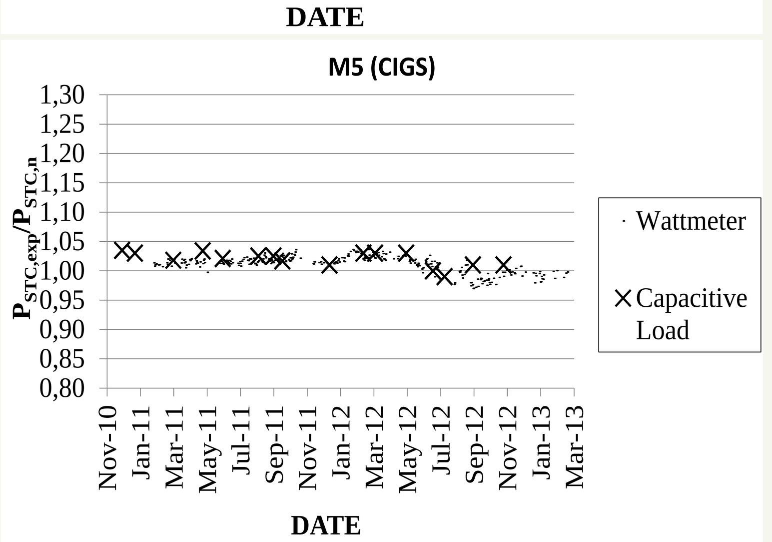
3. STC Power Degradation

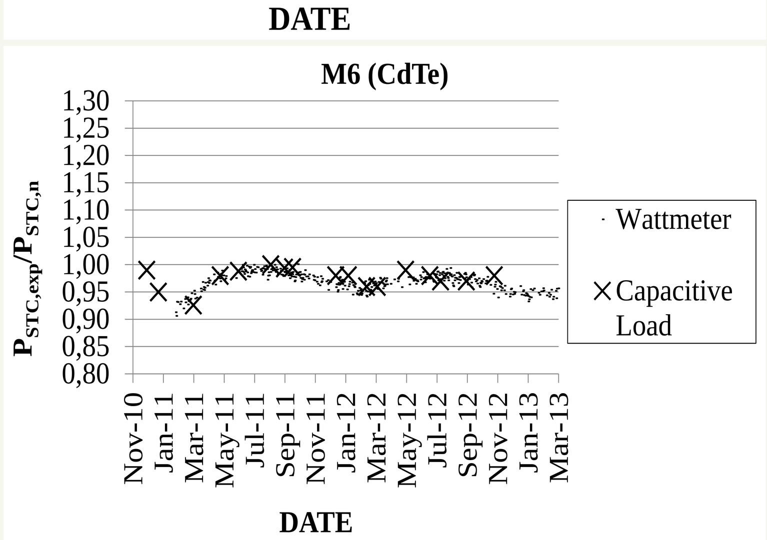












2. Experimental

System characteristics

Modules deployed outdoors at a 30º tilted generator in December 2010.

Manufacturer	Generator	Total Power (W)	γ(%/°C)
M1	Si	2240	-0.45
M2	a-Si	2400	-0.23
M3	a-Si/µSi	2340	-0.28
M4	a-Si/µSi	1890	-0.24
M5	CIGS	1926	-0.446
M6	CdTe	2250	-0.25

Data acquisition system characteristics

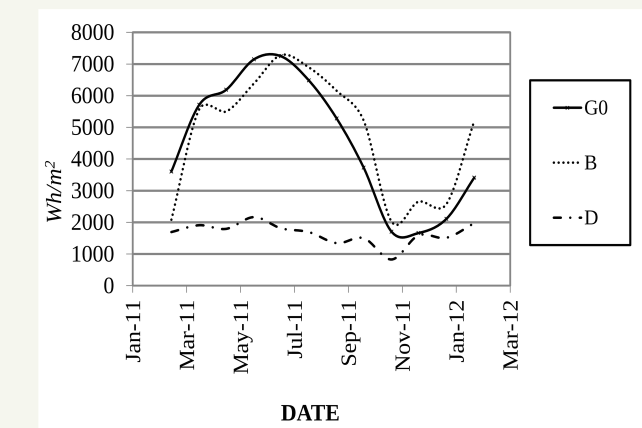
Each generator is connected to a 2.5 kW commercial inverter. As the total power of each generator is lower than 2.4 kW, the inverters will never limit the power. Thus, P_{DC} can be directly considered. DC powers are measured by means of two wattmeters, which give I_{DC} and V_{DC} values. Data is measured every second but recorded as 10 minutes averages.

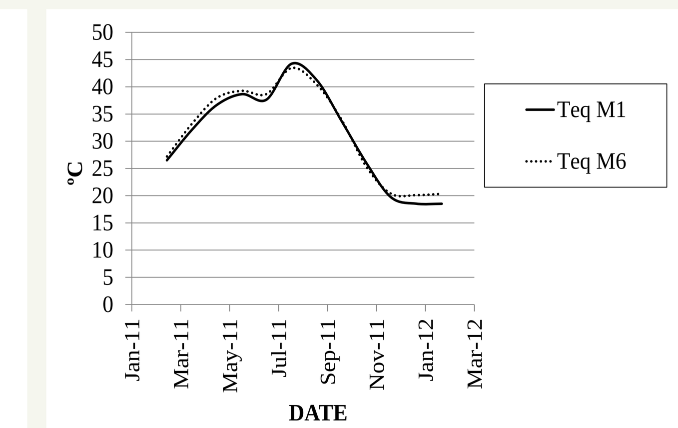
Parameter	Manufacturer	Maximum uncertainty
DC Voltage	Yokogawa	(0.2% of reading + 0.2% of range)
DC Current	Yokogawa	(0.2% of reading + 0.2% of range)
DC Active Power	Yokogawa	(0.3% of reading + 0.2% of range)
IV Characteristic	Photovoltaic Engineering	<1%
Pt100 Temperature	Omega	B Class = 0.3˚C at nominal resistance (0˚C) B Class = 0.8˚C at nominal resistance (100˚C)
Si-x reference modules	Yingli Solar	2% (Calibrated by CIEMAT)

Location characteristics

Location chosen was 42º 04'N, 1º 36'W.

$G_{0,pyr}$, D_{pyr}, B and T_a are registered by means of a meteorological station with a horizontal pyranometer, a horizontal pyranometer with shadowing, a pyrheliometer and a thermocouple.



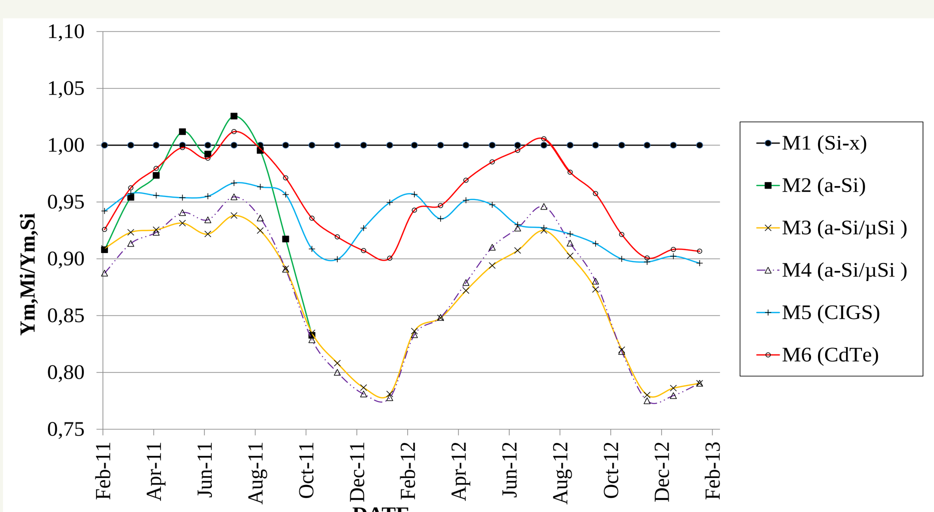


Yearly radiation	Monthly radiation
G_0 = 54266.8 $Wh.m^{-2}$	$G_{0, Min. (Nov. 2011)}$ = 1705 $Wh.m^{-2}$ $G_{0, Max. (Aug. 2011)}$ = 7245 $Wh.m^{-2}$

Month	G_{30} ($kWh.m^{-2}$)	Teq. (C)					
		M1	M2	M3	M4	M5	M6
Nov. 2011	76.63	25.91	25.90	26.45	25.18	28.55	25.20
Aug. 2011	211.13	44.24	44.82	45.86	45,08	43.23	43.46

4. Energy Yield

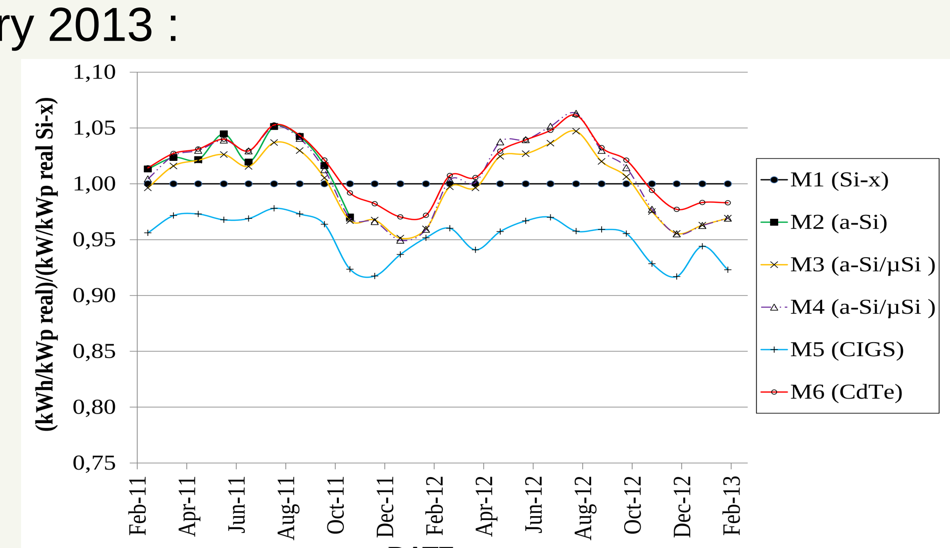
Energy yield referred to the Si-x generator from March 2011 to February 2013 :



Manufacturer	1 (Si-x)	2 (a-Si)*	3 (a-Si/µSi)	4 (a-Si/µSi)	5 (CIGS)	6 (CdTe)
Energy Yield DC (kWh/kWp)	3163.31	1247.46	2774.13	2787.72	2969.53	3042.18
Differences (%) vs Si-x	-	3.33	13.11	12.65	6.53	4.08

*Analysed only from March 2011 to December 2011

Energy yield while all the generators have the same STC power referred to the Si-x generator from March 2011 to February 2013 :



Manufacturer	1 (Si-x)	2 (a-Si)*	3 (a-Si/µSi)	4 (a-Si/µSi)	5 (CIGS)	6 (CdTe)
Energy Yield DC (kWh/kWpreal)	3072.50	1293.65	3092.99	3118.70	2943.39	3135.30
Differences (%) vs Si-x	-	-3.35	-0.70	-1.57	4.39	-2.13

*Analysed only from March 2011 to December 2011

Nomenclature

P_{DC}	continuous power
I_{DC}	continuous current
V_{DC}	continuous voltage
$G_{0,pyr}$	global horizontal irradiance
D_{pyr}	diffuse horizontal irradiance
B	beam irradiance
Ta	air temperature
Teq	equivalent temperature
STC	standard test conditions
$P_{STC,exp}$	experimental power under standard test conditions

5. Conclusions

- Six different currently commercially available generators of different manufacturers have been analyzed under field conditions.
- STC Degradation:
  - Both the Si-x and the CIGS generators have no pattern of measurable degradation.
  - a-Si generator has a rapid initial degradation (35%) overlapped by a seasonal variation in $P_{STC,exp}$ (18%). Similarly, a-Si/µSi generators have a rapid initial degradation (ranging from 15% to 21%) overlapped by seasonal variations in $P_{STC,exp}$ (ranging from 10% to 13%).
  - CdTe generator seems to have a seasonal variation in $P_{STC,exp}$ but smaller than in the a-Si and a-Si/µSi generators (ranging from 6% to 9%).
- In terms of energy, the performance of the TFSC generators without regard to the initial degradation shows that all of them have lower energy yield than the Si-x generator.
- An experimental STC power has been measured to remove the effect of having different $P_{STC,exp}$. Taking into account this $P_{STC,exp}$, TFSC perform similarly to the Si-x in this location.
- Differences in energy yield between manufacturers were mainly due to the difference between their real STC power and the nameplate power given by the manufacturers except in the case of CIGS generator where it had the same performance when taking into account the measured $P_{STC,exp}$.